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THE USE OF ARTIFICIAL CONTRAILS TO INCREASE THE VISIBILITY OF AIRCRAFT

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THE USE OF ARTIFICIAL CONTRAILS TO INCREASE THE VISIBILITY OF AIRCRAFT

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SUMMARY PAGE

THE PROBLEM

The purpose of the present paper is to determine the feasibility of using artificial contrails to aid in the detection of aircraft.

FINDINGS

The results of the present study suggest that it might be advisable to consider carefully the various conditions under which artificial contrails might prove valuable. Some of these conditions which are mentioned are rendezvous, in-air refueling, avoidance of mid-air collisions and identification, undoubtedly there are other instances in which they may be found useful. It was found that artificial contrails are of no value on a direct head-on course. This, however, is an unlikely event as usually there is some angle involved which would permit a smoke trail to be seen. When such angles are present, it is shown that even with the relatively low density smoke utilized in the present study, the visual range is extended from about 8 miles to about 20 to 24 miles. Such an advantage cannot be overlooked when considering such factors as safety, time, and the conservation of fuel.

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INTRODUCTION

The problem of air-to-air visibility has received a great deal of attention in the last few years. A bibliography compiled recently containing some 476 related references is ample testimony to this fact (1). The continuing increases in speed and in altitude of modern aircraft, however, make the problems connected with visibility and detection even more critical than in the past.

Persistent reports of the difficulties encountered in air-to-air search, particularly at high altitudes, have been received at the U.S. Naval School of Aviation Medicine. Such reports were intensified in a series of interviews with pilots in fleet squadrons conducted by the School. These pilots, who are flying the current operational jet aircraft at high altitudes, report serious problems in locating other aircraft known to be in the same area. Specific instances in which this difficulty becomes manifest are in rendezvousing, gunnery training, avoidance of mid-air collisions, identification, and during in-air refueling. Pilots on some occasions have reported spending fifteen to thirty minutes just trying to locate a wingman at high altitudes and in some cases failing completely even when they were in radio contact and had radar facilities. In an incident cited by Tueller (2), "2 jets collided non-fatally with each other under head-on closure, neither seeing the other at any time and not knowing that an accident had occurred until they both had landed." It appears, then, that electronic equipment has not as yet completely replaced the need for visual contact, particularly during flight at relatively high altitudes.

The most serious consequence of decreased visibility in the air is of course the mid-air collision. A recent survey conducted by the Civil Aeronautics Authority (3), cited in (1), revealed that "90% of all the accidents happened within 5 miles of an airport during daylight hours when the visibility was unrestricted. 50% of these accidents within 5 miles of an airport occurred at an altitude of 500 feet or less. Also, a majority of the accidents involved small-type aircraft where one aircraft overtook another."

The problems relevant to visibility and avoidance of collisions under these conditions are of a somewhat different nature from those facing the pilot at higher altitudes. The present paper will deal primarily with those features associated with the latter.

Laboratory investigations have shown that the detection of objects in a homogeneous visual field, such as is encountered at high altitudes, can prove to be exceedingly difficult (4-7). Whiteside (8) and Westheimer (9) have demonstrated that when confronted with a field devoid of visible detail, the eye becomes myopic. Studies of Miller and Ludvigh (4,5), however, indicate that this induced myopia is not the major source of the difficulty.

It has been shown by Irvine and Ludvigh (10, 11) that the eye substantially lacks position sense and that in the absence of differential retinal stimulation the individual does not know the position of his eyes. This would suggest that the problem of locating an object in an empty field is associated more closely with disorientation than with myopia in that the individual pilot not only is unaware of precisely where he is searching but in addition does not know where he has searched previously. The result is a totally unsystematic method of search. It has been shown experimentally that although large objects sometimes are not found readily, the time required for detection is reduced as the size of the object is increased (5).

One way in which both the size and contrast of aircraft can be increased effectively is by the use of artificial smoke streams or contrails. The idea of employing contrails for facilitating air-to-air search is by no means a new one. Military pilots have recognized and utilized such a method for some time. On occasions when locating another aircraft is difficult, the pilots may attempt to rendezvous at an altitude at which the aircraft produce genuine vapor trails. Another method used by pilots in the fleet is to open the dump valves in the wing tanks when possible, thus ejecting fuel which leaves a trail of white smoke. In a discussion of this problem with the Navy's Blue Angel demonstration team, it was brought out that although the smoke generating equipment on their aircraft is for demonstration purposes, occasionally smoke is ejected for purposes of rendezvousing.

Although the advantage to be gained from the use of artificial contrails is obvious, their use apparently has been neglected by both military and civilian authorities alike.

In a recent article concerning mid-air collisions Zeller (12) states, "Smoke puffs and vapor trails have been evaluated. Under certain cruise conditions away from congested traffic these have some limited value. On well-traveled airlines, however, or more particularly in the congested areas around terminal points, the multiplicity of such trails might well lead to confusion, and it is conceivable that the haze condition created could present its own problems."

As mentioned above, it has been shown that most mid-air collisions occur at altitudes under 500 feet and near highly congested areas. Zeller is quite right in saying that under such conditions extensive use of artificial contrails would probably add to the confusion. However, these are not the conditions in which one would expect the contrails to be of most value. One would expect them to be most beneficial in situations encountered at higher altitudes where, in addition to being confronted with a more difficult search problem, the pilot cannot call readily upon ground-based radar for assistance. It perhaps

should be pointed out again that the avoidance of mid-air collisions is but one of the uses of artificial contrails. As mentioned earlier, they may be found beneficial for mid-air refueling, rendezvousing, gunnery practice, and other instances in which the conservation of fuel and time is important.

It has been said by some pilots that a genuine vapor trail can be seen for distances in excess of 100 miles under ideal conditions at high altitudes. In order to determine the actual range of visibility with and without artificial contrails a field study was conducted in the vicinity of Pensacola.

PROCEDURE

Two separate flights were made in connection with this study. The first flight utilized three jet aircraft and was completed in June, 1959. The aircraft employed were one F9F8T (a two seat fighter) and two F11F's (single seat fighters). The second flight was completed in August, 1959 and used only the F9F and one F11F. These aircraft, painted a bright blue and equipped to produce either colored or white smoke trails, are being utilized currently by the Blue Angels for the purpose of demonstrating precision flying. Only white smoke was used in the present study. An experienced aviator was used as chief observer and rode in the spare seat of the F9F. The general flight pattern was determined prior to take-off, but the planes actually were guided throughout the flight by an experienced radar operator. A ground-control intercept radar system was utilized and was operated by trained personnel of the U.S. Air Force. A tape recording was made of the entire conversation taking place among the radar operator, the pilots, and the observer throughout the flight.

The author together with a technical assistant arrived at the radar site shortly before take-off to instruct the radar operator as to the purpose and plan of the study. Following the initial rendezvous the aircraft were guided by the radar operator into position for the first experimental run. The first run was a head-on course, with the plane containing the chief observer at an altitude of 10,000 feet and the target plane at an altitude of 11,000 feet. The initial separation for this run was 20 miles. The true airspeed during this run and subsequent runs was approximately 425 mph. In addition to head-on runs a series of runs was made in which both the target and observer planes flew abreast of each other in the same direction. They would begin such runs with a lateral separation ranging from 30 to 40 miles. The target plane, while attempting to maintain a three o'clock position with respect to the observer plane, would close in at an attack angle of 45-50°. At prescribed intervals the target plane would release smoke from the tail and the observer would be asked to indicate when the target was sighted. A total of ten runs were made during the two flights.

Although most of the data reported was that obtained by the observer sighting the target plane, the pilot in the target plane often verified the sightings by reporting when he sighted the plane carrying the observer.

RESULTS AND DISCUSSION

The results are shown in Table I. It is seen here that for the two direct head-on courses (runs 1 and 3) the target plane was not sighted until it was only $2\frac{1}{2}$ and 3 miles away even when smoke was used. It is, however, not surprising to find that the smoke is of little value during a head-on collision course. Inasmuch as the smoke is ejected directly out of the tail, the size of the aircraft is not increased effectively. Apparently, however, a slight angle of approach definitely increases chances of detection, as is shown in runs 7 and 8 where the target aircraft was sighted considerably sooner at the 1215 and 1400 hours' positions. In this latter instance the observer plane was sighted by the pilot of the target plane at a distance of 8 miles while the target plane itself wasn't sighted until the aircraft were separated by only 3 miles.

It is interesting to note that the visual angle subtended by the F11F is one minute (20/20) at a distance of 3.6 miles when viewed head-on. This approximates closely the distance at which it was sighted. One must keep in mind, however, that although 20/20 vision is considered to be near threshold, the concept is based on the minimum separable acuity. The minimum visible acuity threshold is considerably lower than this. If it were not for the lack of contrast, haze, et cetera, the F11F theoretically should be visible at substantially a greater distance. When considered from a practical standpoint, however, these conditions do exist, and if the observers had not been informed continually as to where to search, it is highly probable that they would not have located the target plane at all. As a matter of fact, on one head-on run not shown in Table I neither aircraft was sighted until one plane was directly over the other (vertical separation of 1000 feet).

Howell (13) conducted a study in which the visibility of a DC-3 was determined for a number of courses. In this study "cockpit conditions were simulated, and observer pilots' searched under 2 conditions, informed and uninformed that they were flying a collision course." Simulated VFR flight conditions were held constant, and four different courses were used. It was found that although theoretically a DC-3 should be seen head-on at a distance of 11.9 miles (average of the four courses), the informed subjects saw it first at an average distance of 4.7 miles and the uninformed at an average distance of 4.1 miles. Thus, the actual sightings were made at about one third the distance at which they theoretically should have been.

Table I

Summary of Visibility Data Collected in Two Flights

	Runs	Initial Separation	Course	Altitude (Ft.)	Background	Smoke	Smoke Released At (Miles)	Sighted (Miles)	Clock Position
Flight 1	1	20 miles	headon	10-11,000	White clouds	none	-------	2½	1200
	2	30 miles	45°	10-11,000	Patchy clouds	none	-------	8	0900
	3	25 miles	headon	10-11,000	White clouds	15 sec steady	25, 12, 5	3	1200
	4	40 miles	45°	20,21,000	Patchy clouds	15 sec steady ten 1 sec burst	40,21 39,30,25	21	0900
	5	30 miles	45°	32-35,000	Clear Blue	15 sec steady	30,25,20	20	0830
	6	30 miles	45°	32-38,000	White clouds & Clear Blue	15 sec steady	24,20	20-24	1500
Flight 2	7	32 miles	headon	20-21,000	White clouds	none	-------	5	1215
	8	30 miles	headon	20-21,000	White clouds	15 sec steady	15, 10	8,3	1400
	9	35 miles	50°	20-21,000	Patchy	10 sec steady	25, 17, 15	15	1430
	10	30 miles	50°	20-21,000	Clear Blue	10 sec steady	28,23,20	20-23	1500

It may be seen in Table I that the visibility range is increased from approximately 8 miles without smoke (run 2) to about 20 to 2' miles with smoke (runs 2,4,5,6,9, and 10) when other than a head-on approach is made. In these runs the planes assumed a parallel course at the initial separation distance at which time the target plane turned toward the observer plane at an angle of 45 or 50 degrees, as described previously. The pilots were informed, by the radar operator, as to the speed required in order to keep abreast of one another. The deviations from the 0900 and 1500 hours' positions shown resulted from wind, drift, et cetera. At prescribed intervals the target aircraft released smoke, either in a steady ten to fifteen second burst or in a series of one second bursts. The smoke actually was produced by ejecting fuel oil into the jet exhaust. Although this produces a white smoke, the density is not great, and it dissipat. . quickly (thirty to sixty seconds). A smoke of a higher density and duration would undoubtedly increase the range at which the aircraft would be located.

It is common knowledge that a genuine vapor trail may be seen easily when the aircraft itself is not visible; under such conditions, the presence of the aircraft is simply inferred. This was clearly the case in run 9 in which the smoke trail of the target plane was sighted by the observer at a distance of 15 miles. The observer reported at the time that the detection was made at the instant the smoke was released and that the plane disappeared from view when the smoke was stopped. The aircraft in this instance did not reappear until it had reached a distance of only 8 miles ·om the observer plane. Several of the observers indicated that the series of one-second bursts was, in their opinion, seen more easily than the steady bursts.

CONCLUSION

It is the opinion of the author that the use of artificial contrails has certain obvious advantages not afforded by other means of increasing the visibility of aircraft. There are of course situations in which their use would be of little value. However, the installation of smoke generating equipment in aircraft in which space and weight limitations are not prohibitive, might soon pay for itself both from an economical standpoint and from one of safety.

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